

The bright and the dark side of Malin 1

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Summary. Malin 1 has long been considered a prototype giant, dark matter dominated Low Surface Brightness galaxy. Two recent studies, one based on a re-analysis of VLA HI observations and the other on an archival Hubble I-band image, throw a new light on this enigmatic galaxy and on its dark/luminous matter properties.

1 Introduction

Malin 1 is a highly unusual disk galaxy characterized by an enormous, HI rich and extremely low surface brightness disk [2, 3]. Recent, deep R-band data by Moore & Parker [4] show an exponential disk extending out to 124 kpc h_{75}^{-1} (scale length 53 kpc). This corresponds to the HI extent. There is also a prominent *bulge*-like component. According to Pickering et al. [3] the rotation curve has the slowly rising shape typical of the less luminous, “dark matter dominated” LSB galaxies. This slow rise of the rotation curve in the presence of a luminous central component is in marked contrast with the rule that there is a close correlation between the distribution of light and the shape of the rotation curve [6]. However, Pickering et al. [3] do point out that their rotation curve is very uncertain because of the low resolution of the observations, the low signal/noise ratio and the strong warping. This has induced us to carry out a re-analysis of the HI data with special attention for the beam-smearing effects and to make a new comparison with the luminosity profile. The results of our analysis agree with those of a recent HST optical study of the bright central component [1]: Malin 1 is a normal, early-type galaxy surrounded by a huge, low-surface-brightness outer disk.

2 New rotation curve and comparison with the luminosity profile

The HI data cube obtained with the VLA by Pickering et al. [3] has been re-analyzed. The large extent of the HI disk is shown in Fig. 1 superposed on the optical (DSS) image. The HI radius corresponds approximately to that of the extended, faint optical disk. A new velocity field has been derived. The 21-cm line profiles are strongly affected by beam smearing and are very asymmetric.

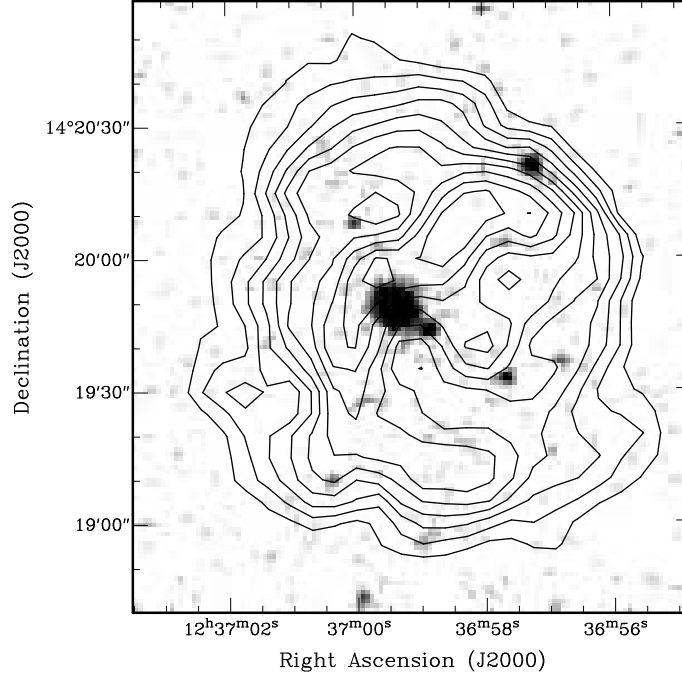


Fig. 1. Total HI map of Malin 1 overlaid on the optical DSS image. Contours run from 7.7 to 49.1×10^{19} atoms cm^{-2} with an increment of 4.6×10^{19} atoms cm^{-2} . The HPBW is $21''$ (~ 29 kpc).

Instead of the intensity-weighted mean velocities used by Pickering et al., which suffer heavily from beam smearing, we have taken the velocities at the profile peaks, close to the high rotation velocity side. Subsequently, the rotation curve has been derived from the velocity field following well-known standard procedures. This rotation curve has been used to construct model data cubes to verify its correctness (Fraternali & Sancisi, in preparation). The new and the old [3] rotation curves are shown in Fig. 2 (bottom). Amplitude and flat outer part are the same. In the inner parts the new curve rises much more steeply and reaches higher values inside 20 arcsec (~ 30 kpc) in correspondence of the central concentration in the luminosity profile (Fig. 2, top). Fig. 3 shows the “maximum disk” decomposition, with isothermal halo and HI disk. The R-band profile [4] has been used. The maximum disk M/L ratio is 5.2 . This is in the range of the values found for luminous early-type galaxies [5].

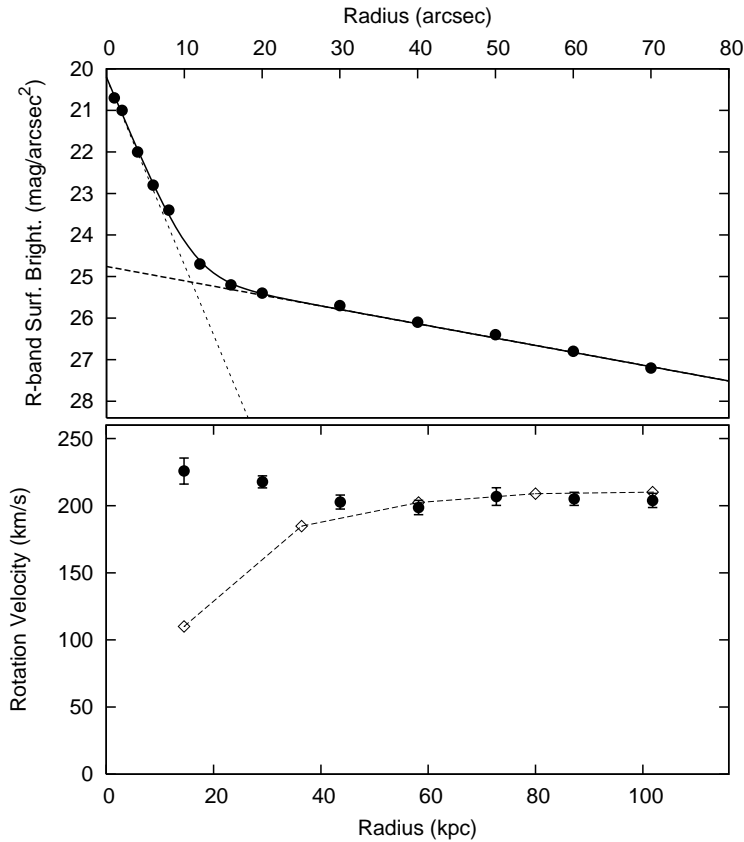


Fig. 2. Mass follows light. Upper panel: R-band luminosity profile derived from Moore & Parker [4] and fitted with two exponential disks. Lower panel: new rotation curve of Malin 1 derived as described in the text (filled circles). The open diamonds show the rotation curve derived by Pickering et al. [3].

3 Conclusions

The present study is based on a re-analysis of existing HI observations of Malin 1 obtained with the VLA. A new rotation curve has been derived. This rotation curve shows a close correlation with the luminosity distribution, in line with the “rule” suggested by Sancisi [6]. Also in this galaxy the mass seems to follow the light. The rotation curve has the shape (steep inner rise) typical of high surface brightness (HSB) galaxies. The classical disk-halo decomposition of the rotation curve has shown that a maximum disk solution is possible. Clearly, in its inner luminous part, Malin 1 has the characteristics of an early-type HSB galaxy.

Barth [1] has recently published a study of Malin 1 based on archival Hubble I-band data. He has examined the structure and the properties of the

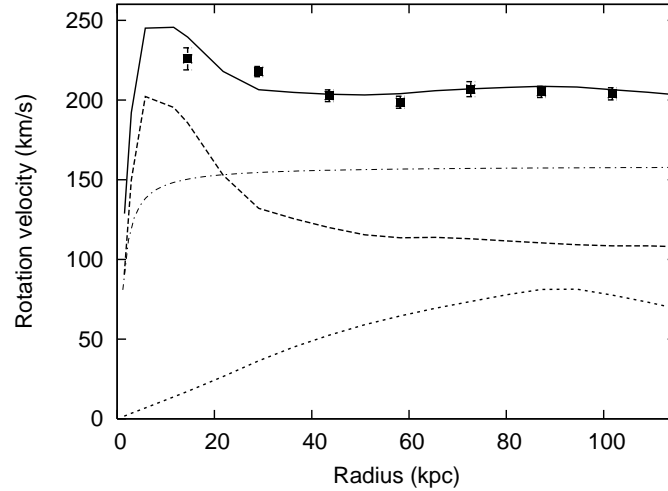


Fig. 3. New rotation curve (squares) of Malin 1 and “maximum disk” mass decomposition. The contributions from the stellar (thick dash) and gaseous (short dash) disks and the DM isothermal halo (dot-dash) are shown. The thick line shows the sum of the three.

inner bright parts and has concluded that Malin 1 has a normal stellar disk and that, out to a radius of ~ 10 kpc, its structure is that of a typical SB0/a galaxy.

The new HI analysis and the optical study throw new light on Malin 1 and on its dark/luminous matter properties. Both point at the same conclusion: Malin 1 is a normal, luminous early-type galaxy. The enigma of the huge (120 kpc), low-surface-brightness stellar and HI disk surrounding the bright inner parts remains. In view of the large-scale symmetry and regularity and of the large orbital period (~ 3.5 billion years) in the outer parts, it seems unlikely that the formation of this extended structure is due to recent accretion and mergers.

We thank Tim Pickering and his co-authors for kindly making their HI data cube available to us.

References

1. Barth, A.J. 2007, *AJ*, 133, 1085
2. Bothun, G.D., Impey, C.D., Malin, D.F., Mould, J.R. 1987, *AJ*, 94, 23
3. Pickering, T.E., Impey, C.D., van Gorkom, J.H., Bothun, G.D., 1997, *AJ*, 114, 1858
4. Moore, L., Parker, Q.A. 2007, *PASP*, in presse (astro-ph/0702551)
5. Noordermeer, E., van der Hulst, J.M., Sancisi, R., Swaters, R.S., van Albada, T.S. 2007, *MNRAS*, 376, 1513
6. Sancisi, R., 2004, *IAUS*, 220, 233S